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ABSTRACT

This module deals with the materials used in making concrete hollow blocks. Topics discussed include: (1) igneous, metamorphic, and sedimentary rocks; (2) weathering (the process of breaking down rocks) and its effects on rocks; (3) cement; (4) stages in the manufacturing of Portland cement; and (5) the transformation of cement into concrete (outlining, in an appendix, chemical changes in the process). A mastery test (with answers), answers to questions asked in the module, a glossary, and list of references are included. (JN)

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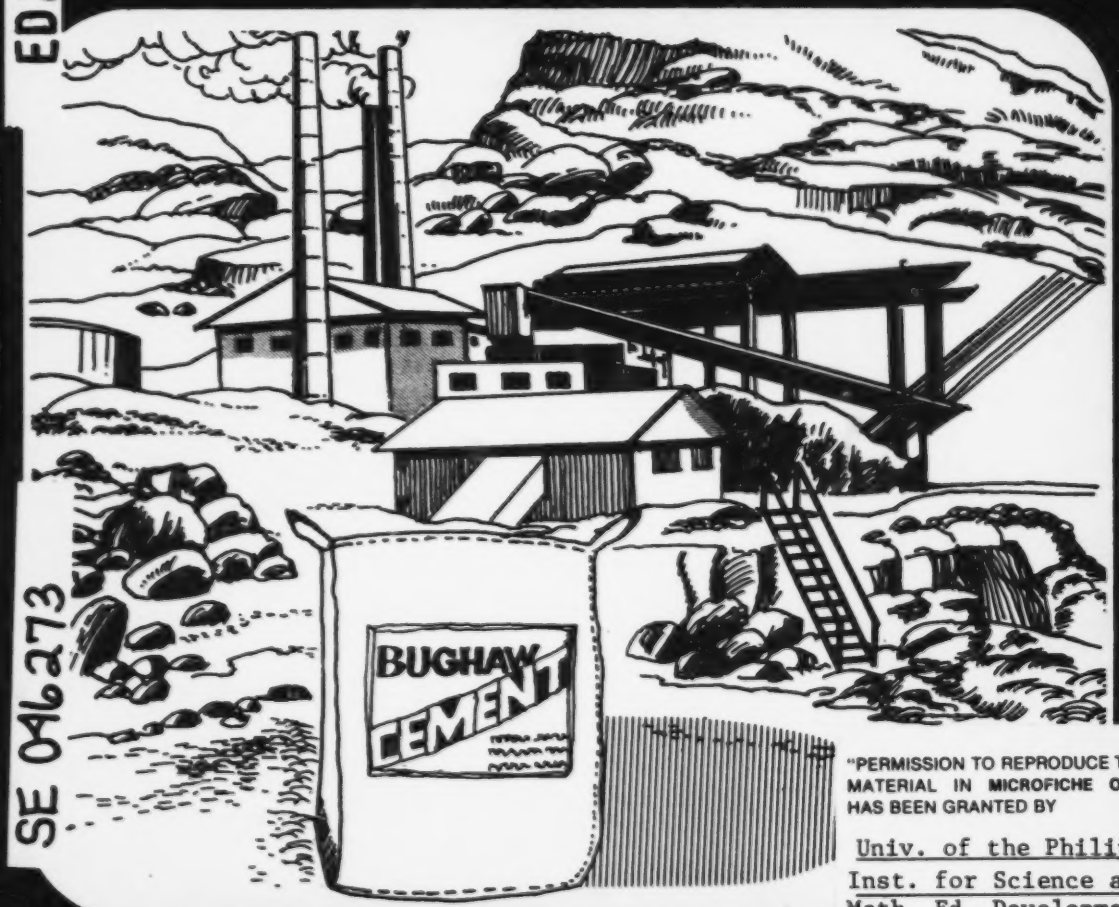

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FROM ROCKS TO CEMENT

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From Rocks to Cement

This module deals with the materials used in making concrete hollow blocks. What are these materials? Where do they come from?

Cement, sand and gravel are the materials used in the production of commercial concrete hollow blocks. These materials come from the land. You have studied in your science class that land is made up of rocks and loose materials such as soil, sand and gravel.

ROCKS

How are rocks formed?

Rocks are mixtures of different minerals. Minerals are inorganic substances: elements or compounds*, which are formed in the earth.

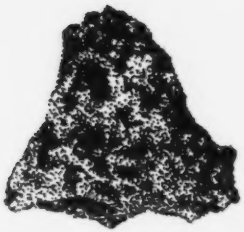
Graphite is a mineral made up of only one element, carbon. Other minerals that are elements are gold, silver and sulfur. Quartz is a mineral, a crystalline compound made up of the elements silicon and oxygen (SiO_2).

Calcite is a compound made up of calcium, carbon, and oxygen. It has the same composition* as calcium carbonate ($CaCO_3$) prepared in the laboratory. Calcium carbonate, however, is not considered a mineral because it is not naturally formed in the earth.

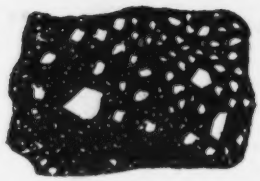
Rocks are classified according to origin (how they were formed) as igneous, sedimentary and metamorphic.

Igneous rocks are formed from melted magma or minerals from deep within the earth. Streams of magma rise from the depth of the earth. Some rise and cool slowly, solidifying underground into rocks with large crystals to form the core of mountains or volcanoes (plutonic). An example of this type of igneous rock is granite. Some magma reach the surface and flow out from volcanoes as lava. Lava cools faster in the air and solidifies into igneous rocks with small crystals (volcanic). Basalt and pumice are examples of this kind of igneous rock.

*Whenever you see an asterisk look at the glossary for the meaning of the word.



granite
(plutonic)



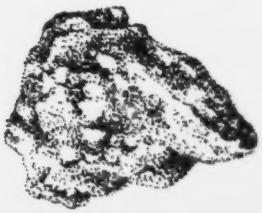
basalt
(volcanic)

SOME IGNEOUS ROCKS

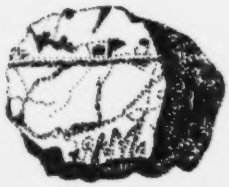
☐ 1. Name the places where you think igneous rocks are found in our country. See map, page 4.

The most common igneous rock is granite. It is a mixture of the minerals, quartz or silicon dioxide (SiO_2), feldspar or potassium-aluminum silicate ($KAlSi_3O_8$) and mica or potassium-hydrogen-aluminum silicate ($KAl_2(OH)_2Si_3AlO_{10}$.)

white crystal
quartz



dark crystal
mica



feldspar

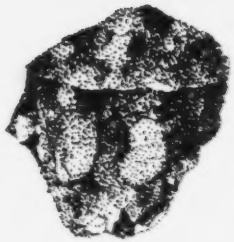
MINERALS FOUND IN GRANITE

Basalt rock is a mixture of minerals containing iron and magnesium and some feldspar.

Sedimentary rocks are formed by sand, mud, and other matter that settled to the bottom of seas and lakes ages ago. With time, these materials became closely packed and stuck together to form rocks.

sandstone

shale

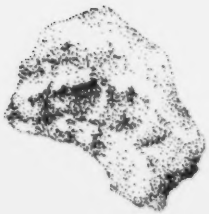


conglomerate

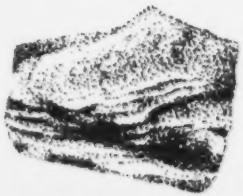
SOME SEDIMENTARY ROCKS

For example, limestone is formed from limy mud; shale from clay mud; bituminous coal from plant remains; conglomerate from gravel; sandstone from sand grains (quartz); sand contains calcite and shell pieces.

☐ 2. Many places in our country are made up mostly of sedimentary rocks. Study map, page 4 and name some of them. Can you say Central Luzon was once under the sea? Why or why not?



marble



quartzite

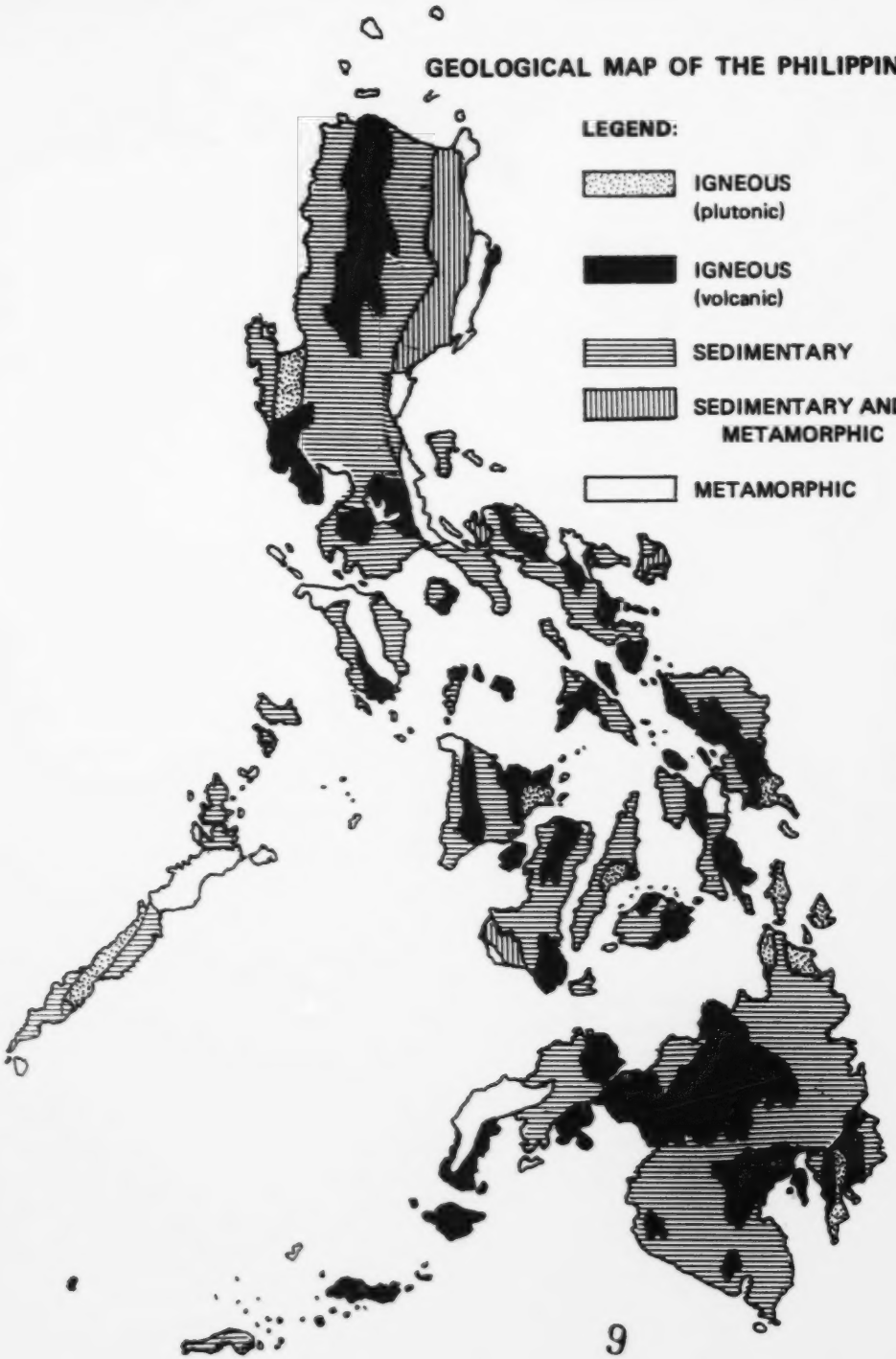
SOME METAMORPHIC ROCKS

Metamorphic rocks are formed from igneous or sedimentary rocks changed by high pressure and temperature within the earth's crust. For example, slate was formed from shale; marble from limestone; anthracite and graphite from bituminous coal, quartzite from sandstone.

☐ 3. What province in our country is famous for its marble deposits? Where else are metamorphic rocks found?

*Answers to questions are given in Appendix A.

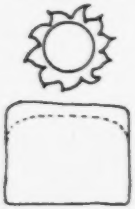
GEOLOGICAL MAP OF THE PHILIPPINES



WEATHERING OF ROCKS

Weathering is the process of the breaking down of rocks. Several factors cause weathering.

CHANGES IN TEMPERATURE



A. expansion or increase in volume

B. contraction or decrease in volume

CHEMICAL DECOMPOSITION

solution

A. oxygen C. bacteria
B. carbon dioxide D. water vapor

A. oxidation C. mineralization
B. carbonation D. hydration

CHANGES IN TEMPERATURE

The outside of rocks increase in volume or expand under the heat of the sun and decrease in volume or contract in the cold of the night more than the inside parts. This unequal change in volume between the inside and outside parts causes rocks to crack.

CHEMICAL DECOMPOSITION

MICROORGANISMS AND PLANTS

Some microorganisms and and plants grow in the cracks. With time, dead organisms, leaves, roots, and plants increase in amount. Bacteria and fungi act on these organic matter. Weak organic acids as acetic acid are produced as one of the products. These acids cause changes in some of the minerals in the rocks to form salts which are soluble in water. This process is called **mineralization** also causes the wearing away of rocks.

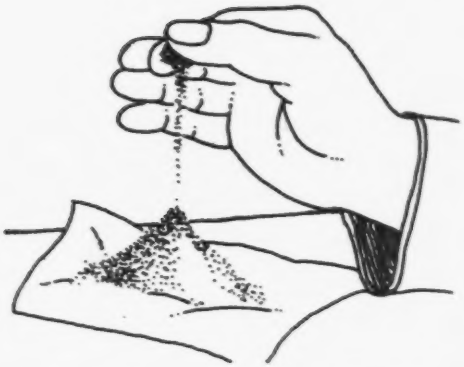
GASES OF AIR

The gases oxygen, carbon dioxide and water vapor of air cause the following chemical changes oxidation, carbonation and hydration respectively. The minerals in rocks break down to form simpler substances, oxides, carbonates and hydrates. The insoluble substances form soil and sand. The soluble ones are dissolved by rain water and in solution are carried away to the sea by ground water.

EFFECT OF WEATHERING

Weathering causes solid rocks to break down into smaller and smaller pieces. Gravel, sand and fine soil particles like silt and clay come from weathered rock. Gravel is coarser than sand. Clay is finer than silt. The thin layer of fine material that covers land is called soil. All soils contain sand, silt and clay in different amounts. If the soil contains more than 50% sand, it is sandy soil. If clay is about 50% of the soil is called clay soil.

You may not be able to analyze soil as soil chemists do, to determine whether it is sandy or clay soil. The following is an easy way to determine whether a sample of soil is sandy or clay soil by some of their properties.



Moisten the soil and rub it between your thumb and first finger. Sandy soil feels gritty and is not sticky. It does not expand when wet and does not crack on drying.

Clay soil when wet is sticky, soft and smooth. It expands when wet and cracks when dry.

The type of soil in an area depends on several factors such as parent rock material vegetation, climate and age of the soil.

Black soil is usually found where the climate is cool, moist and there is vegetation. Blackness in soil is generally due to the presence of humus or partially decayed organic matter. Black soils are found in marshes. Soil rich in humus is very fertile.

Some soils are black because they are rich in manganese, others (Faraon clay) because the parent rock is a limestone rock rich in calcium carbonate. Soils with volcanic ash are also black such as Tagaytay (Batangas) sandy loam, and Tupi (South Cotabato) silt loam. Loam is earth made up of clay, vegetable matter and enough sand to loosen it.

Red soils vary in color from very red to dark reddish brown and light brown to yellow brown. Color differs with amount and kind of iron compounds present in the soil. The red to red brown color of soil is caused by iron oxide. Samples of red soil are the Antipolo (Rizal) clay, Guimbalaon (Negros Occidental) loam, Luisiana (Laguna) clay, and Adtuyon (Cotabato) clay. Red soils are acidic and low in calcium and phosphorous content.

Gray soils have low organic and low iron content. Gray soil is low in fertility and has poor drainage.

White soils are light gray or almost white. These soils are low in iron and organic content. There is an excess of calcium chloride and calcium sulfate which are white solids. This soil is not good for crops.

☐ 4. Take soil from your schoolground, garden, farm, seashore, etc. and classify them according to (1) feel and (2) color.

Chemical changes in rocks such as granite cause the mineral feldspar or potassium silicate ($KAlSi_3O_8$), (see page 2) to change into insoluble aluminum silicate ($Al_2Si_2O_7 \cdot 2H_2O$) and soluble compounds of potassium which dissolve into the soil. Particles of quartz, another mineral in granite rock form pure white sand (SiO_2). Quartz particles mixed with iron oxides make up the sands of the seashore.

☐ 5. If you live near the seashore, borrow a magnet from your physics teacher and pass the magnet near the surface of the sand. Were you able to attract anything from the sand? If you collect anything, what do you think it is?

When it rains, water passes through the soil towards flowing streams until it reaches the sea. It moves along with a great amount of loose particles and dissolved minerals. Insoluble aluminum silicate is sometimes deposited in the beds of streams as pure kaolin. Usually the aluminum silicate mixes with sand and other materials and is then called clay. The suspended materials eventually settle and harden to form sedimentary rocks. Sand and clay deposited into seas and lakes become closely packed and turn into sandstone and shale. Limestone is probably calcite that melted and dissolved originally in seawater.

☐ 6. Where are there clay deposits in our country? What provinces with clay deposits have developed local pottery industries?

Adobe consists of fine particles containing small pieces of minerals and solid lava. Adobe is blown high into the air during a volcanic eruption and settle as volcanic ash which finally becomes closely packed into solid adobe. Adobe is found in many places around Metropolitan Manila, particularly in Quezon City. Adobe is often cut into blocks for building material. The lands cultivated into rice fields in Makati, Alabang in Rizal, Imus and Tanza in Cavite were formerly adobe. Gray in color and sticky when wet adobe soil drains poorly, because water can only pass through it slowly.

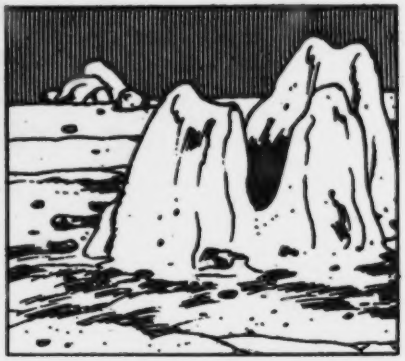
CEMENT

Cement is one of the materials used in the production of all kinds of construction hollow blocks. The name cement is given to materials that harden in water as well as in air.

You may ask when was the first cementing material discovered?

You can imagine an aborigine building a fire in a hole surrounded with pieces of limestone, calcium carbonate ($CaCO_3$), or gypsum, hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$) rocks. Heat changes part of the rocks. Limestone breaks down into lime, calcium oxide (CaO) and carbon dioxide (CO_2); gypsum loses part of the water combined with it.

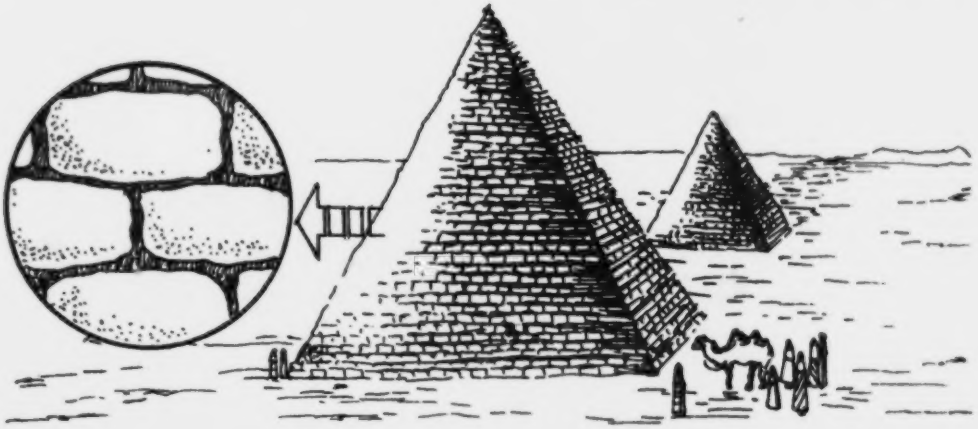
Heat changes part of the rocks.



Rain wets the powder and binds the pieces of rocks together.

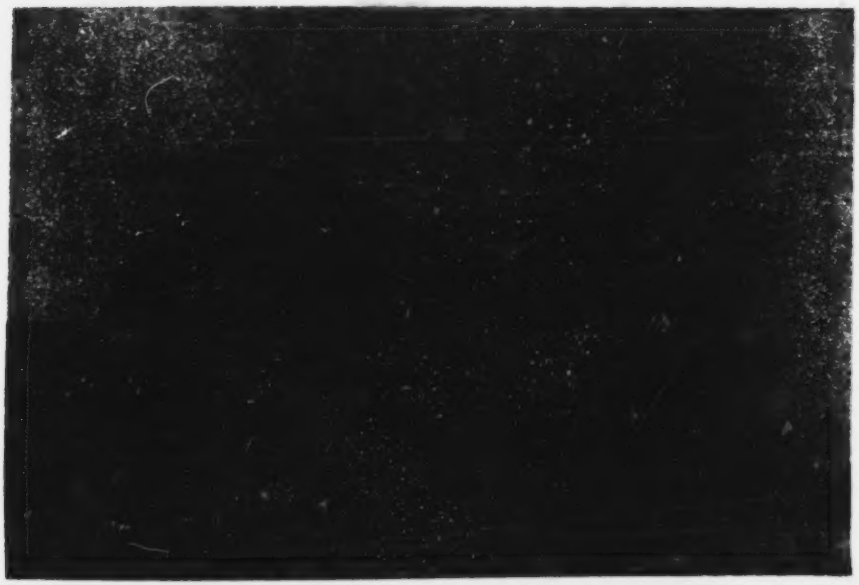
Powdered lime and water-free gypsum fall between the pieces of rocks. A slight rain in the night enters between the pieces of rock and wets the powder. The resulting products have binding properties and bind the pieces of rock together producing the first stone construction.

Materials with great power to bind blocks of stone were used by the early Egyptians. The Egyptian pyramids which have been able to stand destructive atmospheric forces throughout the ages and still stand today are a proof of this.



The Greeks and Romans used calcium oxide mixed with sand, gravel, broken tiles or bricks as binding materials in building the Roman Pantheon, the Colosseum, churches and other structures.

Some of our old churches were built of similar materials.



Today, portland cement is the most important cement in terms of production quantity. Portland cement was first made by a brick mason, Joseph Aspdin, of Leeds, England. He called the cement, portland, because when used for making concrete, the result looked like a natural stone found on the Isle of Portland.

MANUFACTURE OF PORTLAND CEMENT

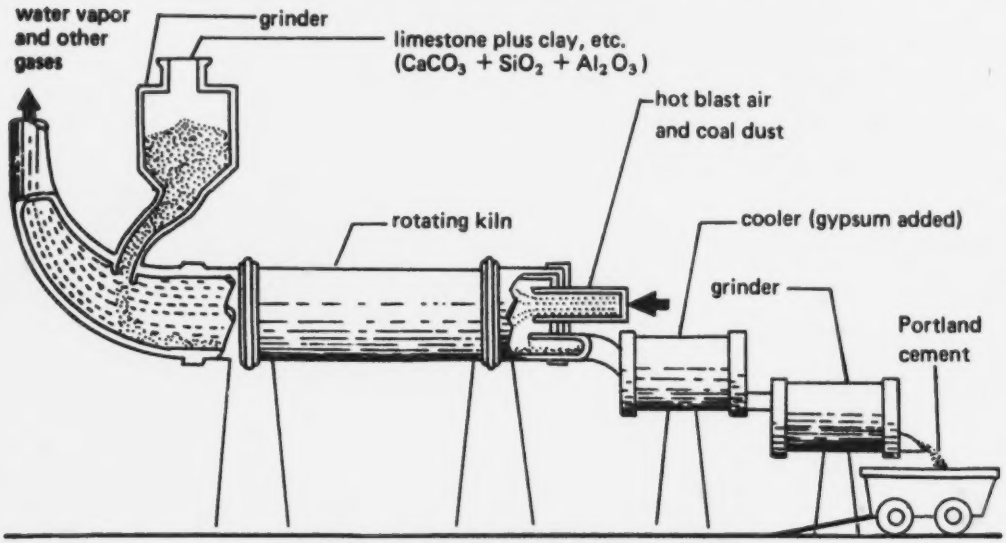
Out of experience and following the formulas experimentally obtained by engineers, and chemists, the ranges in the amounts of the materials that can be mixed to produce cement have been set up. Within these ranges the mixture behaves satisfactorily in the heat treatment to produce good cement.

The factory chemist's problem is what combination of the available natural materials can produce good quality and inexpensive cement.

He solves the problem by analyzing the materials. By calculations, he then determines what combination of the materials will satisfy the ideal composition range of cement. Sometimes he finds that he needs to add another type of rock to get the correct amounts. In addition to limestone and clay, he sometimes has to add sandstone or iron ore. He then performs trial runs to test the properties of the product.

There are three stages in the commercial manufacture of cement: (1) preparation of the natural materials; (2) heat treatment; (3) clinker cooling and grinding.

Close control of all the manufacturing stages is necessary.



STAGES IN THE PRODUCTION OF CEMENT

1. Natural materials

Portland cement is a mixture of limestone and clay in proportions to contain 75% calcium carbonate, 25% aluminum silicate, and free silica. The mixture is ground into fine powder and well mixed with water to form a slurry*.

2. Heat treatment

The slurry now undergoes heat treatment in a long rotating* kiln using gas, oil, or coal dust.

At the cooler end of the kiln, water from the slurry is removed at 100°C. The temperature is increased to about 1450°C at the hot end of the kiln burning off any organic matter. Carbon dioxide (CO_2) is also removed at this end with the breaking down of calcium carbonate ($CaCO_3$) into calcium oxide (CaO) and carbon dioxide (CO_2). The high temperature is continued long enough to partially change the cement compounds into small round marbles called "clinker".

The clinker is greenish-black in color showing a glass-like luster and bright glistening specks.

A clinker is a heterogeneous mixture* of about one mole* of tri-calcium aluminate ($Ca_3Al_2O_6$), and calcium silicates consisting of two moles of dicalcium silicate, Ca_2SiO_4 and great amounts of tricalcium silicates, Ca_3SiO_5.

3. Clinker cooling and grinding

The clinker is cooled, mixed with about 2-3% gypsum ($CaSO_4 \cdot 2H_2O$), and then ground into fine powder in a ballmill (a rotating cylindrical mill filled with steel balls).

The composition of portland cement in terms of oxides of the elements is as follows:

COMPOSITION OF PORTLAND CEMENT

Oxide	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	Na_2O; K_2O
%	58-67	19-26	4-11	2-5	0-5	0-2.5	0-3

If there is a cement factory in your city, province or town your class can make a field trip to it. Observe the different stages of manufacture, the control laboratory and the antipollution devices.

TRANSFORMATION OF CEMENT INTO CONCRETE

Portland Cement is mixed with fine and coarse materials usually sand and gravel, and water in the production of concrete. Sand and gravel are added to decrease the amount of cement needed.

When water is added to cement, a series of chemical changes take place giving products which bind the materials together. The result is concrete, a product of such hardness and resistance to compression* and tension* that it has become one of the great structural materials of this industrial age.

Its use has become part of our daily life experience. It is used in the building of houses, roads, bridges, farm silos, dams, runways, or landing fields for airplanes, swimming pools, protective walls from atomic radiation and for many other structural purposes.

If you are interested in the chemical changes that take place when cement is transformed into concrete read Appendix C.

Answer the following mastery test to find if you have understood what you have read in this module.

1. If you live in areas near volcanoes which one of the following kinds of rocks will be found in your area?

   1. sedimentary
   2. igneous
   3. metamorphic
   4. none of the above.

2. Riceland that is sticky when wet and cracks when dry contains a high percentage of:

   1. silt
   2. sand
   3. clay
   4. gravel

3. A rock sample shows shell pieces in it. To what class of rock does it belong?

   1. sedimentary
   2. igneous
   3. metamorphic
   4. none of the above

4. Boiling water is poured into a thick walled glass container. The glass cracks. Based on your knowledge of the effect of temperature on rocks, which of the statements below explains the cracking of the glass?

   1. Glass is made of weak material.
   2. Boiling water causes equal changes in volume of the inside and outside walls of the glass.
   3. The outside wall of the glass increases in volume more than the inside wall.
   4. The inside wall increases in volume more than the outside wall.

5. Since Antipolo soil is reddish brown, which of the oxides below is present?

   1. manganese oxide
   2. calcium oxide
   3. iron oxide
   4. aluminum oxide

6. Soil in our country is usually acidic in regions of much rainfall because the rain washes away soluble basic salts. Which of the following suggestions easily shows whether or not your farm soil is acidic?

   1. Taste the soil.
   2. Send it to be analyzed.
   3. Feel it.
   4. Use litmus paper.

7. Which of the materials below are used in producing portland cement?

   1. limestone and clay.
   2. gravel and sand.
   3. silt and clay.
   4. gypsum and lime.

8. In the manufacture of cement what does the heat treatment remove?

   1. water
   2. organic matter
   3. carbon dioxide
   4. all of the above

9. Weak organic acids are produced by the action of fungi or bacteria on organic matters. These acids react with some of the minerals in the rocks. What do you call this process?

   1. Oxidation
   2. Mineralization
   3. Sedimentation
   4. Carbonation

To check your answers see Appendix B.

GLOSSARY

Adhesion – attraction of the molecules or particles on the surface of two different bodies in contact causing them to stick together. **Cohesion** on the other hand is attraction of the molecules or particles of a body causing them to unite throughout the whole mass.

composition or make-up – In science, composition gives the amounts of the elements that make up a compound. It may be in terms of the number of atoms of the elements in a formula unit of the compound or the mass of the elements in a formula mass or the % of the elements in the compound. Ex.: The composition of water is 2 atoms of hydrogen and one atom of oxygen in a formula unit (H_2O) of the compound, or 2 grams of hydrogen and 16 g of oxygen, in 18 g of water or 11.1% hydrogen and 88.9% oxygen by mass.

compounds – are substances made up of a fixed number of atoms of two or more different elements. Ex.: water (H_2O) silver oxide (Ag_2O), rust (Fe_2O_3).

compression – coming closer together under the action of an applied force.

elements – are substances which cannot be chemically broken down into simpler substances. Elements are made up of only one kind of atoms. Atoms are the smallest unit particles of matter that can take part in a chemical change. Ex.: gold (Au), silver (Ag), hydrogen (H), oxygen (O), iron (Fe).

gel – is a kind of colloidal mixture. A colloidal mixture has solid particles suspended in a liquid. These particles are bigger than the particles of solution but not visible to the unaided eye. A gel is a colloidal mixture where the solid particles and the liquid form a jelly-like mixture. Examples are gelatin and agar in water.

heterogeneous mixture – a mixture in which the unlike materials can be seen.

hydrates – a compound containing water chemically combined in its composition. Ex.: gympsum, $CaSO_4 \cdot 2H_2O$.

hydrolysis – a chemical change between water (HOH) and another substance wherein water breaks down into (H) and OH groups.

impermeable – not allowing passage through it.

intermeshed – entangled as in a net.

mole – matter is made up of particles that have mass and volume. A mole may be expressed as 6.02×10^{23} particles or as the mass in grams, or as the volume of these number of particles in the gas form at standard condition of temperature and pressure (0°C and 1 atmospheric pressure). Ex.: a mole of carbon dioxide has a 6.02×10^{23} particles of carbon dioxide with the formula CO_2. It may also be the mass of 6.02×10^{23} number of particles which is equal to the **formula mass in grams**

$C = 12\ g$
$2(O) = 2 \times 16 = 32\ g$
$12\ g + 32\ g = 44\ g$

It may also be the volume of 6.02×10^{23} particles at 0°C and one atmospheric pressure or 22.4 liters.

rotating – turning around an axis.

saturated – a liquid is said to be saturated when it holds in solution the greatest amount of a substance that it can dissolve at a given temperature.

slurry – a thick mixture of solid materials with water in the manufacture of portland cement by the wet method.

tension – stretching under a pulling force.

APPENDIX A

ANSWERS TO QUESTION IN THE MODULE

1. Igneous rocks are found near volcanoes like at Mayon in Legaspi in the Bicol region, Taal in Batangas, the Mountain Province, and the hills in Bataan. They are also found around Mt. Kanlaon in Negros, in Samar and in Northwestern Mindanao.

2. Sedimentary rocks are found at the foothills of Teresa, Rizal, in Sibul, Bulacan, and in Bauang, La Union.

   The presence of sedimentary rocks in most of Central Luzon shows that the area was probably under the sea centuries ago.

3. Romblon is well known for its marble deposits. National development has renewed efforts to discover more of our natural resources. Deposits of good quality metamorphic marble has been discovered in the towns of Labo, Paracale, and Jose Panganiban in Camarines Norte.

   Romblon marble is of the surface boulder type. Bicol marble is found underground in flat lands, below the surface. It is found as layers in jet black, gray, brown, flesh, becoming whiter with depth. It is almost snow white at a depth of 10 meters. This marble is similar to the world famous Carrara marble of Italy. Romblon marble is only 50% calcium carbonate $CaCO_3$ and 50% impurities. Bicol marble has an average of 98% $CaCO_3$.

   Metamorphic rocks are also found in Palawan, Mindoro, and Zamboanga.

4. Your answers will differ depending on your source of soil. Classification according to feel will give either sandy or clay soil. Classification according to color will be black soil (fertile humus soil), red soil (rich in iron oxides, acidic and low in calcium and phosphorous content), gray soil (low in fertility, organic and iron content), white soil (low in iron and organic content with excess of white calcium chloride and calcium sulfate).

5. If you can attract with a magnet a substance from seashore sand, it will probably be magnetic iron oxide, Fe_3O_4.

6. Clay deposits are found in Libjo and Pallocan, in Batangas City. Local potters usually manufacture "palayok" or cooking pots and "paso" or flower pots using primitive methods. Products are crude. Batangas City officials have set up a training center in Libjo. Techniques are being taught to manufacture products using the local clay.

APPENDIX B

KEY TO MASTERY TEST

1. 2
2. 3
3. 1
4. 4
5. 3
6. 4 Litmus paper turns red in acid and blue in base.
7. 1
8. 4
9. 2

APPENDIX C

CHEMICAL CHANGES IN THE TRANSORMATION OF CEMENT INTO CONCRETE

When powdered cement mixes with water, a fast violent chemical change takes place giving off much heat. This is caused by the action of water on the oxides of calcium and aluminum present in cement (see table page 11).

$$\underset{(3\,CaO\cdot Al_2O_3)}{Ca_3Al_2O_6} + 6HOH \rightarrow 3Ca(OH)_2 + 2Al(OH)_3 + \text{heat}$$

The water becomes saturated* with the hydroxides and a fast setting takes place. The addition of gypsum slows down this setting because gypsum reacts with $Ca_3Al_2O_6$. The hydrolysis* of the oxides of calcium and silicon ($3CaO \cdot SiO_2$) Ca_3SiO_5, present in the largest amount in cement, begins with the first setting and continues slowly until all of it is used up.

$$\underset{(3\,CaO\cdot SiO_2)}{Ca_3SiO_5} + 4\frac{1}{2}\ H_2O \rightarrow CaSiO_3 \cdot 2\frac{1}{2}H_2O + 2CA(OH)_2$$

A colloidal gel* is formed which is soft and contains much water and unreacted cement grains. The gel forms in the spaces between cement grains. Further reaction of the cement grains causes water to be removed from the gel which becomes hard and impermeable*. Particles between the grains are now densely packed. Some parts, however, are less packed causing empty spaces. Crystallization of $Ca(OH)_2$, which fills the spaces, binds the cement grains. Surface setting results as $Ca(OH)_2$ reacts with carbon dioxide of the air to form $CaCO_3$. Hardening is caused by the formation of a gel of calcium alumina silicate hydrates* which later crystallizes as intermeshed* crystals. Concrete strength depends on the -Si-O-Si bonds of the calcium silicate ($CaSiO_3$) chain structure.

The strength and hardness depends not only on these bonds but also on the adhesion* between the crystals and the aggregates. For example, there is a strong adhesion between calcium-silicates and sand.

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